[Proc. Roy. Soc. Victoria, 26 (N.S.), Part I., 1913].

Art. XV.—*On the Estimation of the Position and Slope of the Foramen Occipitale Magnum.*

By L. W. G. BÜCHNER

(Government Research Scholar in the Department of Anthropology, Melbourne University).

(With one Text Figure).

[Read 10th July, 1913].

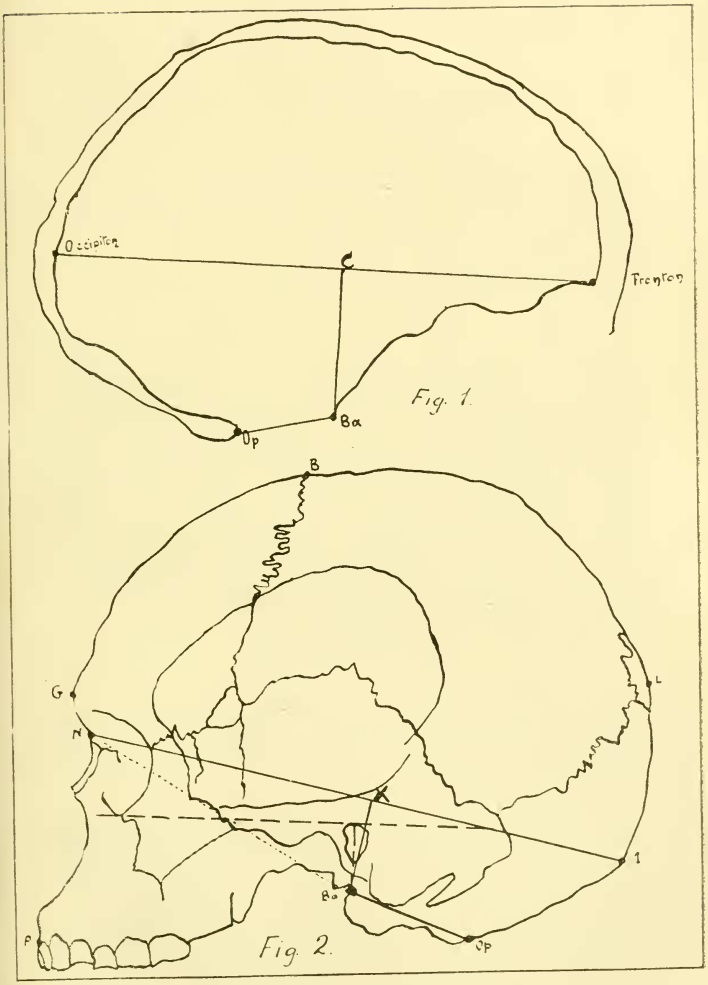
In 1909 Bolk[1] published a work concerning the estimation of the displacement, position and slope of the *foramen occipitale magnum*.

In describing its position he refers to the fact that in *Mycetes* the *foramen* lies very near "the occipital pole of the skull, so that the condition is found which is the rule with other mammals; sometimes, as in man, it lies about the middle of the cranial base." The same writer[2] also states that, "Together with the variations in position the inclination of the plane of the *Foramen magnum* also generally changes."

As the question of the earlier history of the *foramen occipitale magnum*, and of the base lines from which have been estimated its position and slope has been already fully considered by Bolk, it is unnecessary to pursue the question further in the present paper.

In view, however, of the much more recent work accomplished by this author, on the *foramen occipitale magnum*, it will be necessary for me to examine his methods in some little detail, inasmuch as they form the basis of the present investigation. Bolk introduces a new baseline estimated in the bisected skull. He says, "As frontal point I chose the lowest point of the frontal wall of the skull, where the interior surface . . . bends inwardly in a more or less sharp curve, to be continued in the roof of the nasal cavity." He further states that "the determination of this point presents no difficulties as a rule, since in the median plane the interior surface of all Primate skulls possesses a distinct frontal wall, which may be more or less inclined, and may pass more or less gradually into the cranial wall, but which is still always present."

This author then goes on to say that "in the median all Primate skulls possess a front. On both sides of the median plane this frontal wall disappears, since the roof of the orbitae approaches


Occipital
Frontal
Up
Ba
Fig. 1.
B
G
N
L
1
Ba
P
Op
Fig. 2.

very closely under the cranial roof, so that the cranial plane, and the orbital roof join under an acute angle." This anterior point is called the "Fronton."

The posterior cranial point is also obtained on the bisected skull. For its determination the greatest distance from the fronton to a point on the posterior wall is estimated with the aid of compasses. Bolk further says, "With the lower Primates this point can, as a rule, be determined at once." In man, however, and especially in juvenile skulls, it is not so easily estimated. Bolk found that very often no definite point could be determined for the Occipiton, as it is termed, for he found that infrequently "a fairly large part of the interior surface of the skull in the median plane describes a circular arc." Where this was the case, the middle of this circular arc was always chosen as the posterior point."

It is obvious that this base line, from fronton to occipiton, as Bolk himself points out, is determined by the shape and form of the skull, and is thus distinguished from other planes, which are more or less dependent on fixed cranial points. From this base line is determined the position, displacement and slope of the *foramen occiptale magnum*. The position he calculated by means of an index basalis, whilst the slope is determined by the Basal Angle. The former is constructed by dropping a line at right angles from the fronton-occipiton plane, which cuts the basion. This base line is thus divided into two parts at the point C (see fig. 1). As Fc becomes greater it follows that the basion retreats, and this is expressed by the formula

$$\frac{\text{Fc} \times 100}{\text{Fo}} = \text{Index basalis.}$$

By comparing the basal indices of the anthropoid and man, Bolk found that a considerable difference existed between them, the average indices of the human skulls being 15 units less than that of the anthropoid.

In his second paper, the same author discusses the "slope of the foramen magnum in Primates. The slope is estimated by again employing the fronton-occipiton base line. As before, a line is projected from the base line at right angles, and cutting the basion. From this projected line c Ba (fig. 1) is estimated the inclination of the slope of the *foramen* by calculating the angle which the plane c Ba forms with the basion-opisthion plane Ba Op.

It appears to me that Bolk's methods of determining the position and slope of the *foramen occipitale magnum* are beset by at least

two grave objections. Before a skull can be examined by Bolk's method it must be bisected. This in itself constitutes an almost insuperable difficulty, for, notwithstanding Huxley's[3] now out-of-date dictum that, "it shall be an opprobrium to an ethnological collection to possess a single skull which is not bisected longitudinally," the science of comparative craniology has so far advanced as to render the bisection of skulls unnecessary for modern investigations.

The second objection I find against Bolk's method, is, that there is a difficulty in determining the frontal point. As already defined, this point is "the lowest point of the frontal wall of the skull where the interior surface . . . bends inwardly in a more or less steep curve, to be continued in the roof of the nasal cavity." After examining a number of bisected Australian aboriginal crania, I find it is not always possible to determine this point with accuracy. The crista frontalis is projected into the skull in many cases for several millimetres.

Bolk himself says that in the skulls of the Javanese, with one exception, he found a "frontal crest projecting very far into the cranial space." From this it would appear that a considerable difficulty may be experienced in attempting to determine the exact position of the fronton, for as the crista frontalis projects, so will it affect the basal index. It seems, therefore, that this latter objection, which has been raised, would appear to be a real one. It is, then, difficult to see how Bolk's new base line can ever serve as the basis of a craniometrical system, particularly in view of the objection that it necessitates the bisection of every skull, and without such bisection it is completely useless.

The objects of the present paper are two in number. The first is to record certain observations based mainly on the median sagittal diagrams of some fifty-two Tasmanian crania, and the second is to ascertain from certain of these observations by means of biometric analysis, which method is the best to apply to non-bisected skulls for the determination of the position and slope of the foramen occipitale magnum. The observations I have recorded are eight in number, and are as follows:—

(1) The length of the foramen occipitale magnum, measured from basion to opisthion.

(2) The greatest breadth of the foramen occipitale magnum.

(3) The foraminal index.

$$\frac{\text{Breadth of foramen} \times 100.}{\text{Length of foramen}}$$

(4) Broca's occipital angle. (See fig. 2.) The angle is continued by the nasion-basion, and basion-opisthion planes.

(5) The foraminal angle based on the Frankfort plane. (See fig. 2.)

(6) The nasion-inion length.

(7) The basal index. (See fig. 2.)

(8) The basal angle. (See fig. 2.)

Of the above observations, numbers 1 and 2 were estimated directly on the skull by Professor Berry and Dr. Robertson in 1909, and for permission to utilise these figures I have to express my thanks to these authors. Number 6 has also been recorded elsewhere,[4] by the present writer. The remainder of the observations are the original contribution of the present work, and for which I am responsible.

For determining the position and slope of the foramen occipitale magnum, I have employed three distinct methods.

Of these, the first is Broca's well-known occipital angle, the second is determined by utilising the Frankfort Plane as a base line, and the third is the original method of the present work, and is based on the nasion-inion plane.

As Broca's method is so well known, and has already been referred to, there is no necessity for any further explanation concerning it.

For the second method I have utilised the Frankfort plane as a base line. Bolk has referred to the fact that Huber[5] also determined the slope of the *foramen* by using this plane on non-bisected skulls. Bolk further states that he considers it to be a method which is preferable to others when the skull cannot be bisected. Unfortunately, this work is not available in Melbourne, nor is any abstract of it available. The method which I propose to use, therefore, may or may not be original. In any case, whatever observations are based on the Frankfort plane, will only give the inclination of the slope of the *foramen*, and not its position and situation on the skull base. The method I have adopted is to project a line downwards at right angles to the Frankfort plane, and cutting the basion. The angle which this line makes with the basion-opisthion plane determines the foraminal angle (see fig. 2).

As Bolk also points out, the inaccuracy which accompanies the estimation of angular measurement by direct observation is lessened by constructing projections on a suitable base line. He says, "The position of every point in the skull varies on its own

account, since on every point a large number of factors have a localising influence." Two of these points may have a number of factors in common. Therefore, if in two skulls the angle bounded by these points is found to vary, this difference is not to be accounted for by the shifting of one point only. I have, therefore, estimated the inclination of the slope of the foramen in the manner just described.

The third method of determining both the position and slope of the *foramen* is a modification of that described by Bolk, save that the base lines are different. The base line which I propose to use in the nasion-inion plane. It has been pointed out by Schwalbe,[6] Cunningham,[7] Berry and Robertson,[8] as well as myself,[4] that this plane is an important one in comparative craniology. The several observations recorded by the above investigators all serve to support this contention. Another reason—and a strong one—is, that in Berry and Robertson's Atlas of Tracings of Tasmanian crania[9] the necessary points are accurately denoted, so that observations may be estimated direct from the tracings in the median sagittal plane. My reasons for utilising this plane as a base line would, therefore, appear to be quite valid.

For the determination of the position and slope of the *foramen*, by adopting the procedure already recorded when describing Bolk's method, I have constructed a basal index, and a basal angle. As before a line is dropped at right angles from the base-line—in this case the nasion-inion plane—and cutting the basion (see fig. 2). The basal index is then calculated by taking the ratio, which NX bears to NI, the latter being referred to as 100.

$$\text{Basal Index} = \frac{\text{NX} \times 100}{\text{NI}}$$

The Basal Angle is likewise determined by estimating the angle which is contained by the two planes, X Ba and Ba Op (see fig. 2). As the method is adopted from Bolk's work, any further explanation is deemed unnecessary.

The material on which the present paper is based will be found in Berry and Robertson's Atlas of Tracings of Fifty-two Tasmanian Crania. All the observations recorded in table I., with the exception of the two already referred to, namely, the length and breadth of the foramen, have been estimated direct from the tracings in the median sagittal plane; that is, in the *norma lateralis*. As number 48 has previously been shown to be that of a juvenile, all the observations recorded on it have been omitted from the table of generalised results.

In Table I the generalised results estimated biometrically are set forth. The nature of the observations, the true means, with their probable errors, the standard deviations with their probable errors, together with the minimum and maximum figures for each observation, are displayed in their respective orders.

TABLE I.

TASMANIAN CRANIA.

Nature of Observation.	Number.	Min.	True Mean and Prob. Error.	Standard Deviation and Prob. Error.	Max.
1 - Length of *For. occ. magnum*	37	31	35.78±0.82	2.89±0.22	41
2 - Breadth of *For. occ. magnum*	38	26	29.43±0.27	2.55±0.19	35
3 - Foraminal Index	36	68	82.59±0.59	5.26±0.41	100
4 - Broca's Angle	38	154	163.64±0.59	5.39±0.41	178
5 - Foraminal Angle (Büchner)	33	91	100.24±0.54	4.62±0.38	107
6 - Nasion-Inion Length	45	145	170.97±0.66	6.60±0.46	183
7 - Basal Index (Büchner)	38	43	52.71±0.28	2.69±0.20	58
8 - Basal Angle (Büchner)	38	85	92.71±0.46	4.35±0.33	106

A study of Table 1 reveals some interesting facts. It will be noted that, as judged from the standard deviations, the observations numbers 7 and 8, which are based on the nasion-inion plane, are less variable than 5 or 6, which are estimated by Broca's method, or the Frankfort plane method. The standard deviation for both the Basal Index, number 7, and the Basal Angle, number 8, are shown to be very small.

This, therefore, would appear to support the contention referred to in an earlier part of this work, that the nasion-inion plane is really the best from which to estimate the slope and approximate position of the *foramen occipitale magnum*.

In order to compare the figures of Table I with those of other races, I have utilised several plates of Berry and Robertson's Atlas of Australian Crania, in order to obtain the necessary data. As this work[10] is in the hands of the printer, I have to express my thanks to Professor Berry and Dr. Robertson for allowing me to use their original drawings. The observations which I have recorded are taken from the first 52 tracings of Normae A.

The observations which I have recorded are as follows:—

5. Basal Index.
6. Basal Angle.
7. Foraminal Angle (Frankfort Plane).
8. Broca's Occipital angle.

The other source of comparative data I have abstracted from Bolk's works. The generalised results for both the Australian and Bolk's figures are set forth in Tables ii. and iii. respectively.

These results have been obtained in precisely the same manner as those of the Tasmanian, and, therefore, need no further explanation.

TABLE II.

Australian Crania.

Nature of Observation.	True Mean and Prob. Error.	Standard Deviation and Prob. Error.
5. Broca's Angle - - -	162.28±0.48	- 5.21±0.35
6. Foraminal Angle (Büchner)	106.98±0.44	- 4.8 ±0.31
7. Basal Index (Büchner) -	52.47±0.24	- 2.60±0.17
8. Basal Angle (Büchner) -	91.72±0.40	- 4.37±0.29

TABLE III.

Bolk's Observations.

Nature of Observation	True Mean and Prob. Error.	Standard Deviation and Prob. Error.
Index Basalis - - -	45.84±0.26	- 2.74±0.18
Basal Angle - - -	99.68±0.58	- 5.11±0.41

Again, by comparing the observations (7 and 8) based on the nasion-inion plane with those based on Broca's and the Frankfort Plane methods, it will be noted that the former are the least variable.

In Table iv. the results for each observation in the Tasmanian-Australian groups, together with those furnished by Bolk, are set forth in order of their variability. In each instance, the observations based on the nasion-inion plane, which concern the present work, are the least variable, whilst the angular measurements based on Broca's and the Frankfort Plane methods show the greatest variability, which is sufficiently high to preclude them from further consideration.

In conclusion, when further comparative data are available, a better test will be afforded as to the practicability of the original methods herein described. From the material available it is clear that the observations based on the nasion-inion plane are the more accurate. The present work also furnishes another proof that the bisection of crania is unnecessary.

TABLE IV.

Nature of Observation.	Race.	No.	True Mean and Prob. Error.	S.D. and Prob. Error
Basal Index (Büchner) - -	Australian	- 52 -	53.47±0.24	- 2.60±0.17
Basal Index (Büchner) -	Tasmanian	- 38 -	52.71±0.28	- 2.64±0.20
Index Basalis (Bolk) -	Various Races	- 50 -	45.84±0.26	- 2.74±0.18
Basal Angle (Büchner) -	Tasmanian	- 38 -	92.71±0.46	- 4.35±0.33
Basal Angle (Büchner) -	Australian	- 52 -	91.72±0.40	- 4.37±0.29
Foraminal Angle (Büchner) -	Tasmanian	- 33 -	100.24±0.54	- 4.62±0.38
Foraminal Angle (Büchner) -	Australian	- 52 -	106.98±0.44	- 4.80±0.31
Basal Angle (Bolk) - -	Various Races	- 50 -	99.68±0.58	- 5.11±0.41
Broca's Angle - - - -	Australian	- 52 -	162.21±0.48	- 5.21±0.35
Broca's Angle - - - -	Tasmanian	- 38 -	163.64±0.59	- 5.39±0.41

REFERENCES.

(1) Bolk, P.—On the position and displacement of the Foramen Magnum in the Primates. Proceedings Koninklijke Akad. van Wetenschappen te Amsterdam. Translated from: *Verslag van de gewone vergadering der Wisen. Natuurkundige Afdeeling van Zaterday*, 27 Nov., 1909, Dl. xviii.

(2) Bolk, P.—On the Slope of the Foramen Magnum in Primates. *Ibid.* [Jan. 26, 1910.]

(3) Huxley, T. H.—*Man's Place in Nature*. Macmillan and Co., London, 1897.

(4) Büchner, L. W. G.—A study of the Curvatures of the Tasmanian Aboriginal Cranium. *Proc. Roy. Soc. Edin., in course of publication.*

(5) Huber, L.—*Vergleichung des Hylobates und Menschenschädels.* München, 1902.

(6) Schwalbe, G.—Studien über *Pithecanthropus erectus*, Dubois. *Zeit für Morph. und Anthrop.* Bd 1, Heft 1.

(7) Cunningham, D. J.—The Australian Forehead. Anthropological Essays, presented to Edward Burnett Tylor, in honour of his 75th birthday, Oct. 2, 1907.

(8) Berry, R. J. A., and Robertson, A. W. D.—The Place in Nature of the Tasmanian Aboriginal, as Deduced from a Study of His Calvaria. Part I. *Proc. Roy. Soc. Edin.*, vol. xxxi., pt. 1, No. 3.

(9) Berry, R. J. A., and Robertson, A. W. D.—Dioptrographic Tracings in Four Normae of Fifty-two Tasmanian Crania. *Trans. Roy. Soc. Vic.*, vol. v., 1909.

(10) Berry, R. J. A., and Robertson, A. W. D.—Dioptrographic Tracings in Three Normae of Ninety Australian Crania. *In the Press.*